IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : G. FINKELSHTAIN et al. Conf. No. 9110

Serial No : 10/796,305 Group Art Unit: 1795

Filed : March 10, 2004 Examiner: R. Alejandro

For : SELF-CONTAINED FUEL CELL AND CARTRIDGE THEREFOR

COVER LETTER REGARDING EXECUTED RULE 1.131 DECLARATION

Commissioner for Patents
U.S. Patent and Trademark Office
Customer Service Window, Mail Stop ______
Randolph Building
401 Dulany Street
Alexandria, VA 22314
Sir:

The undersigned points out that the executed Rule 1.131 Declaration being filed herewith includes copies of pages 1, 3 and 4 of an executed Declaration forwarded to the law firm of the undersigned by facsimile from the Inventors, and page 2 of the Rule 1.131 Declaration along with all of the pages of Exhibit A, which were added by the law firm of the undersigned, and which are identical to pages 1 – 4 of the Rule 1.131 Declaration (including Exhibit A) forwarded to the Inventors for execution.

Further, the law firm of the undersigned has been advised that the Inventors reviewed all pages of the Rule 1.131 (including all pages of Exhibit A) before executing the Rule 1.131 Declaration.

Accordingly, Applicant respectfully submits that the present Rule 1.131 Declaration is properly executed and should be considered as filed in executed form.

Should there be any questions regarding this paper, please contact the undersigned at the below-listed number.

Respectfully submitted,
G. FINKELSHTAIN et al.

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DECLARATION UNDER 37 C.F.R. 1.131

Sir:

We, Gennadi Finkelshtain, Mark Estrin and Rami Hashimshony, do hereby declare:

1. We are the inventors of the subject matter disclosed and recited in at least independent claims 1, 39 and 93 of the above-identified application.

2. We completed the invention of at least claims 1, 39 and 93 (and those claims dependent thereon) in the United states and/or the WTO country of Israel before March 5, 2003, as evidenced below.

CONCEPTION

3. Before March 5, 2003, we conceived of a refillable fuel cell comprising a casing, a cathode having a first surface and a second surface, at least part of the second surface being exposed to the atmosphere, an anode having a first surface and a second surface, a first chamber configured to retain liquid fuel, wherein the first chamber is defined at least partially by the first surface of the

anode, and a second chamber configured to retain liquid electrolyte, wherein the second chamber is defined at least partially by the second surface of the anode and the first surface of the cathode, wherein the fuel cell is configured to be sealed in a substantially liquid-tight manner during at least a portion of its service life, and wherein the fuel cell is configured to at least one of receive fresh liquid and discharge spent liquid via at least one resealable opening, as recited in each of claims 1-38.

4. Before March 5, 2003, we conceived of a self-contained, refillable fuel cell comprising a cathode having a first surface and a second surface, at least part of the second surface being exposed to the atmosphere, an anode having a first surface and a second surface, a first chamber filled at least partially with a liquid fuel, the first chamber being defined at least partially by the first surface of the anode, a second chamber filled at least partially with a liquid electrolyte, the second chamber being defined at least partially by the second surface of the anode and the first surface of the cathode, at least one sealable opening communicating with the first chamber, at least one other sealable opening communicating with the second chamber, and a cartridge, wherein the fuel cell is configured to at least one of receive fresh liquid and discharge spent liquid from and/or to the cartridge via the sealable openings, as recited in each of claims 39-73.

5. Before March 5, 2003, we conceived of a fuel cell system comprising a fuel cell assembly comprising a cathode having a first surface and a second surface, at least part of said second surface being exposed to air, an anode having a first surface and a second surface, a first chamber configured for containing a liquid fuel, said first chamber being defined at least partially by said first surface of said anode, wherein said first chamber has a first liquid transfer port and a second liquid transfer port, said first and second ports being normally closed, a second chamber configured for containing a liquid electrolyte, said second chamber being defined at least partially by

said second surface of said anode and said first surface of said cathode, wherein said second chamber has a third liquid transfer port and a fourth liquid transfer port, said third and said fourth ports being normally closed and a cartridge removably connected to the fuel cell, as recited in each of claims 93-101

6. Evidence of such conception as disclosed and recited in claims at least claims 1, 39 and 93 (and those claims dependent thereon) of the application, is shown in the draft application (hereinafter referred to as "the Invention Disclosure") attached hereto as Exhibit A. The Invention Disclosure attached hereto is a photocopy of, and is substantially identical to, an original marked-up draft application prepared and forwarded to patent counsel before March 5, 2003. Drawing substantially similar to the drawings filed in the instant US application were also provided, but are not provided with the attached Invention Disclosure. Applicant notes, however, that certain portions of the marked-up draft application have been blacked-out or redacted..

7. The benefits and features of the recited invention are shown and described in the Invention Disclosure (18 pages of specification.

DUE DILIGENCE

8. At least Inventor Gennadi Finkelshtain communicated with patent counsel, Heribert F. Muenstener, numerous times before March 5, 2003 in preparing a patent application based on the Invention Disclosure.

9. At least Inventor Gennadi Finkelshtain worked diligently on the preparation of the patent application by first submitting the Invention Disclosure to patent counsel Heribert F. Muenstener on a date prior to March 5, 2003.

10. After the invention disclosure was received by patent counsel Heribert F.

Muenstener, at least Inventor Gennadi Finkelshtain worked diligently on the preparation of the patent application with patent counsel Heribert F. Muenstener until a final draft patent application was completed to the satisfaction of the inventors. Communications took place between Gennadi Finkelshtain and Heribert F. Muenstener regarding the draft application during a time period of at least between January 3, 2003 and March 11, 2003, the US filing date of the provisional application No. 60/453,218 of which the instant application claims priority under 35 USC 119(e).

11. A final draft of the patent application was forwarded to the Inventors for review on March 10, 2003. The application was approved for filing in the U.S. Patent and Trademark Office on March 11, 2003 and was filed on March 11, 2003.

12. We declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further, that the statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Gennadi Finkelshtain — 18.05.2008 Date

Mark Estrin — 13.05.2008 Date

Rami Hashimshony — 16.05.2008 Date

EXHIBIT A

APPLICATION FOR PATENT

Inventor: Genadi Finkelshtain, Mark Estrin, Rami Hashimshony

Title: Refillable Fuel Cell System

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a refilling system, in particular, it concerns a refillable liquid fuel cell and a refilling device.

By way of introduction, an electrochemical liquid fuel cell is a device that converts the energy of a chemical reaction into electricity. Among the advantages that fuel cells have over other sources of electrical energy are a high efficiency and environmental friendliness. Although fuel cells are increasingly gaining acceptance as electrical power sources, there are technical difficulties that prevent the widespread use of fuel cells in many applications, especially mobile and portable applications.

A fuel cell produces electricity by bringing a fuel into contact with a catalytic anode while bringing an oxidant into contact with a catalytic cathode. When in contact with the anode, the fuel is oxidized at catalytic centers to produce electrons. The electrons travel from the anode to the cathode through an electrical circuit connecting the electrodes. Simultaneously, the oxidant is catalytically reduced at the cathode, consuming the electrons generated at the anode. Mass balance and charge balance are preserved by the corresponding production of ions at either the cathode or the anode and the diffusion of these

ions to the other electrode through an electrolyte which the electrodes are in contact.

As the fuel cell produces electricity, the liquid fuel and the electrolyte are gradually exhausted of their useful components. After a period of use, the spent liquid fuel and the spent electrolyte need to be removed from the fuel cell and replaced or otherwise the fuel cell needs to be disposed of.

Disposing of the fuel cell is not a preferred option as the relative expensive assembly of the fuel cell makes the price of each cell too high for the fuel cell to be a viable option for many applications.

Refilling the fuel cell presents other difficulties due to hazardous nature of the spent liquid fuel and the spent electrolyte.

There is therefore a need for a refillable liquid fuel cell system.

SUMMARY OF THE INVENTION

The present invention is a refillable fuel cell system construction and method of operation thereof.

According to the teachings of the present invention there is provided, [TO BE COPIED IN FROM CLAIMS WHEN FINALIZED]

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is an isometric view of a refillable fuel cell system, having a refillable fuel cell and a refilling device, that is constructed and operable in accordance with a preferred embodiment of the invention;

Fig. 2 is an exploded isometric view of the refillable fuel cell of Fig. 1;

Fig. 3 is a cross-sectional view of the refillable fuel cell of Fig. 1 through a plane which is parallel to lines A-A;

Fig. 4a is an exploded isometric view of a turbulence reducing arrangement of the refillable fuel cell of Fig. 2;

[redacted]

Fig. 5a is an exploded isometric view of the refilling device of Fig. 1;

Fig. 5b is a cross-sectional view of the refilling device of Fig. 1 through a plane which is parallel to lines B-B;

Fig. 6 is an axial sectional view of a valve arrangement, prior to coupling, for use with the refillable fuel cell system of Fig. 1;

Fig. 7 is an axial sectional view of the valve arrangement of Fig. 6 which is partially coupled;

Fig. 8 is an axial sectional view of the valve arrangement of Fig. 6 which is fully coupled;

Fig. 9 is an isometric view of the refillable fuel cell system of Fig. 1 which is interlocked;

Fig. 10 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 prior to refilling the refillable fuel cell;

Fig. 11 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 during refilling the refillable fuel cell; and

Fig. 12 is a cross sectional view, through a plane which is parallel to lines A-A, of the refillable fuel cell system of Fig. 9 after refilling the refillable fuel cell.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a refillable fuel cell system construction and method of operation thereof.

The principles and operation of the refillable fuel cell system according to the present invention may be better understood with reference to the drawings and the accompanying description.

Reference is now made to Fig. 1, which is an isometric view of a refillable fuel cell system **10**, having a refillable fuel cell **12** and a refilling device **14**, that is constructed and operable in accordance with a preferred embodiment of the invention. As refillable fuel cell **12** produces electricity, the liquid fuel and the electrolyte of refillable fuel cell **12** are gradually exhausted

of their useful components and are defined as spent liquid fuel and spent electrolyte. An example of a preferred fuel is a suspension of $NaBH_4$ in an $NaBH_4$ saturated KOH solution, as described in co-pending U.S. Application No. 10/230,204, which is incorporated by reference for all purposes as if fully set forth herein. A preferred example of a suitable electrolyte is also KOH solution. The spent liquid fuel and the spent electrolyte are removed from refillable fuel cell **12** and a replacement liquid fuel and a replacement electrolyte are inserted into refillable fuel cell **12** by refilling device **14**. In accordance with a most preferred embodiment of the present invention, the spent liquids are removed from refillable fuel cell **12** into refilling device **14** and replacement liquids are inserted by refilling device **14** into refillable fuel cell **12** substantially simultaneously. Moreover, refilling device **14** stores the spent liquids in substantially the same volume that the replacement liquids were stored. However, it should be noted that fuels and electrolyte are still maintained in separate volumes within refilling device **14**. In accordance with a first alternate embodiment of the present invention the removal of the spent liquids and the insertion of the replacement liquids are not performed simultaneously. In accordance with a second alternate embodiment of the present invention the refilling device **14** stores the spent liquids and the replacement liquids in separate volumes.

Reference is now made to Figs. 2 and 3. Fig. 2 is an exploded isometric view of refillable fuel cell **12**. [redacted]

[redacted] Refillable fuel cell **12** has a fuel cell assembly **16**. Fuel cell assembly **16** includes two electrode assemblies **18**, which share a common fuel chamber **30**. The choice of the number of electrode assemblies and their dimensions are design considerations which depend on the required electrical output, as will be clear to one ordinarily skilled in the art. Fuel cell assembly **16** also includes a bottom housing portion **58**, a top housing portion **60**, three gas evacuation devices **62**, two side casings **64**, a central housing portion **68** and a plurality of conductive plates **66**. [redacted] 3, which is a cross-sectional view of refillable fuel cell **12** of Fig. 1 through a plane which is parallel to lines A-A. Each electrode assembly **18** includes a cathode **22** having two surfaces **20**, **21**. At least 80% of surface **20** is exposed to air. Each electrode assembly **18** also includes an anode **24** having two surfaces **26**, **27**. Fuel cell assembly **16** also includes two electrolyte chambers **28**. Each electrolyte chamber **28** contains an electrolyte and is defined at least partially by bottom housing portion **58**, top housing portion **60**, surface **21** of cathode **22** and surface **26** of anode **24**. Fuel chamber **30**, which contains a liquid fuel, is disposed between electrolyte chambers **28**. Fuel chamber **30** is defined at least partially by bottom housing portion **58**, top housing portion **60**, surfaces **27** of anode **24**, which faces out of electrode assemblies **18**. Fuel chamber **30** has two openings, a lower opening **34** and an upper opening **36**. Reference is again made to Fig. 2. Lower opening **34** is provided with a normally-sealed fluid transfer port, exemplified by a valve **38**,

and upper opening **36** is provided with a normally-sealed fluid transfer port, exemplified by a valve **40**. Valve **38** and valve **40** are normally sealed. Valve **38** is disposed below the fluid level of the liquid fuel in fuel chamber **30**. Valve **38** is disposed in the lower section of fuel chamber **30** and valve **40** is disposed in the upper section of fuel chamber **30**. This, together with other precautions described below, helps to ensure that, when valve **38** and valve **40** are open and a replacement liquid fuel is introduced into fuel chamber **30** via valve **38** and the existing liquid fuel is removed from fuel chamber **30** via valve **40**, the replacement liquid fuel and the existing liquid fuel flow substantially laminarly within fuel chamber **30** which helps reduce mixing of the existing and the replacement liquid fuel. This concept can also be understood by defining the majority of the flow of the existing and replacement liquid fuel flowing through chamber **30** by a plurality of substantially parallel primary flow vectors. The distance between valve **38** and valve **40** measured parallel to the primary flow vectors is equal to the maximum dimension of chamber **30** measured parallel to the primary flow vectors. Fuel cell assembly **16** also includes a turbulence reducing arrangement **50** which further enhances laminar flow, as described above, within fuel chamber **30**. Turbulence reducing arrangement **50** will be described below in more detail with reference to Fig. 4a. Electrolyte chamber **28** is generally similar to fuel chamber **30**. For example, each electrolyte chamber **28** has two openings, a lower opening **42** and an upper opening **44** (Fig. 3). Lower opening **42** is provided with a valve **46** and upper opening **44** is provided with a valve **48**.

Valve **46** and valve **48** are configured, disposed and perform similar functions to valve **38** and valve **40** of fuel chamber **30**, respectively.

Reference is now made to Fig. 4~~a~~, which is an exploded isometric view of turbulence reducing arrangement **50**. Turbulence reducing arrangement **50** is disposed within fuel chamber **30**~~,~~. In the case shown here where filling is from the bottom of the chambers, turbulence reducing arrangement **50** is preferably close to the bottom of the chamber, i.e., near the inlet ~~thereof~~ ~~(~~see Figs. 2, 3). Turbulence reducing arrangement **50** may be implemented in many ways including, but not limited to, ~~includes~~ ~~a~~ a layer of permeable material **52**, such as permeable foam, which provides hydraulic damping. By way of a non-limiting example, the permeable foam can be non-woven polypropylene foam with a weight of between 80 and 100 grams per square meter. In the example shown here, layer of permeable material **52** is disposed between two mesh layers **54** which serve to retain layer of permeable material **52**. Layer of permeable material **52** and mesh layers **54** are held in place by a frame **56**. Turbulence reducing arrangement **50** is disposed horizontally within fuel chamber **30**, i.e., substantially perpendicular to the primary direction of fluid flow during refilling. When valve **38** (Fig. 2) and valve **40** (Fig. 2) are open and a replacement liquid is introduced into fuel chamber **30**, layer of permeable material **52** helps disperse the replacement liquid fuel which is entering fuel chamber **30** across fuel chamber **30** to promote laminar flow of the replacement liquid fuel. It should be noted that all orientations, for example: bottom, horizontal etc., are used for the sake of brevity assuming the device is standing

upright as shown, but, the invention can alternatively be implemented in other orientations.

Referring briefly to ~~Fig. 4b is a cross-sectional view of~~ gas evacuation devices 62 ~~of refillable fuel cell 12 of~~ (Fig. 2)~~. By way of introduction~~, it will be appreciated that gases accumulate in chamber **30** and chambers **28**. These accumulated gases need to be evacuated from refillable fuel cell **12** without allowing any of the hazardous liquids to escape. Therefore, one gas evacuation device **62** is disposed above each of chamber **30** and chambers **28**. Gas evacuation device **62** is configured to enable escape of accumulated gas and to prevent escape of liquids. Gas evacuation device **62** may be implemented as any suitable opening or valve which equalizes gas pressure while preferably providing protection against spillage of the liquids within the chambers. [redacted]

Reference is now made to Fig. 5a, which is an exploded isometric view of refilling device **14**. Fig. 5b is a cross-sectional view of the refilling device of Fig. 1 through a plane which is parallel to lines B-B. Refilling device **14** has a

fluid replacement assembly **70**. Fluid replacement assembly **70** has a main body **94**, a top housing portion **96**, a bottom housing portion **98**, a front cover **100** and a plurality of sealing gaskets **102**. Fluid replacement assembly **70** includes a parallel-walled chamber **72** containing a replacement liquid fuel. Chamber **72** is mainly defined by main body **94**, top housing portion **96** and bottom housing portion **98**. Chamber **72** has an upper valve **74** and a lower valve **76**. Upper valve **74** is configured for coupling with valve **40** (Fig. 2) and lower valve **76** is configured for coupling with valve **38** (Fig. 2). Chamber **72** also includes a fluid flow actuating arrangement **78** which is configured to substantially simultaneously remove the spent liquid fuel from refillable fuel cell **12** via valve **74** and supply the replacement liquid fuel to refillable fuel cell **12** via valve **76**. Fluid flow actuating arrangement **78** includes a piston **88** which is configured to move vertically within chamber **72**. Upper valve **74** is disposed near the top of chamber **72** and lower valve **76** is disposed near the bottom of chamber **72** such that, when lower valve **76** and upper valve **74** are open, the spent liquid fuel entering chamber **72** via upper valve **74** is kept substantially separate from the replacement fluid exiting chamber **72** via lower valve **76** by piston **88**. Piston **88** is spring loaded. Piston **88** also includes a retaining rod **89** which is generally interlocked with a shaped slot in a release bar **92**. Retaining rod **89** and release bar **92** are collectively defined as a retaining arrangement. Retaining rod **89** is released by lateral displacement of release bar **92** causing a release of piston **88**. A safety lock **90** prevents releasing of piston **88** by accidentally displacing release

bar **92**. Fluid replacement assembly **70** also includes two parallel walled chambers **80** containing a replacement electrolyte. Two chambers **80** are mainly defined by main body **94**, top housing portion **96** and bottom housing portion **98**. Each chamber **80** has an upper valve **82** and a lower valve **84**. Upper valves **82** are configured for coupling with valves **48** (Fig. 2) and lower valves **84** are configured for coupling with valves **46** (Fig. 2). Each chamber **80** also includes a fluid flow actuating arrangement **86** which is configured to substantially simultaneously remove spent electrolyte from refillable fuel cell **12** via valve **82** and supply replacement electrolyte to refillable fuel cell **12** via valve **84**. Fluid flow actuating arrangement **86** and upper valve **82** and lower valve **84** are configured substantially the same as the corresponding elements of chamber **72**. It will be apparent to those skilled in the art that refilling device **14** can be used to replace other liquids. Additionally, refilling device **14** can be implemented with one or more chambers.

In particularly preferred implementations, refilling device 14 is implemented as a disposable device produced primarily from lightweight low-cost materials. For this reason, at least the main body of the device (main body **94**, top housing portion **96** and bottom housing portion **98**) are preferably made of polymer materials which are suitable to withstand exposure to the chemicals used. Preferred examples of polymer materials include, but are not limited to, PVC and polyurethane. In practice, substantially all components of the refilling device 14 (other than those with specific mechanical requirements such as springs) are preferably implemented from such polymer materials.

Reference is now made to Figs. 6, 7 and 8. It will be understood that the liquid transfer ports and docking ports of the fuel cell and refilling device respectively are configured to mate in order to allow replacement of the fuel cell liquids, and must re-seal on separation to prevent leakage of the contained liquids from either device. To this end, the preferred features of these ports include reliable non-drip mating and re-sealing, while maximizing flow rates as much as possible when open. It will be understood that any ports which provide these features may be used. Preferred examples include, but are not limited to, mechanically interlocking valves and self-sealing plugs pierced by hollow needles. One particularly preferred implementation will now be exemplified with reference to Figures 6-8.

Fig. 6 is an axial sectional view of a valve arrangement **104**, prior to coupling, for use with refillable fuel cell system **10** of Fig. 1. Fig. 7 is an axial sectional view of valve arrangement **104** of Fig. 6 which is partially coupled. Fig .8 is an axial sectional view of valve arrangement **104** of Fig. 6 which is fully coupled. By way of introduction, the valves, alternatively described as ports, of the present invention and their coupling, alternatively described as docking, are subject to design constraints which include the following factors. First, the dead space between the valves needs to be minimized to prevent hazardous liquids dripping from the exterior of the valves after the liquids have been replaced. Second, other precautions need to be incorporated to prevent dripping. Third, the cross-sectional area of the valves needs to be as large as possible to ensure good flow rates. By way of example, valve arrangement **104**

illustrates the coupling of upper valve **74** and valve **40**. However, it should be noted that corresponding valves of refillable fuel cell **12** and refilling device **14** are configured to operate in substantially the same way as upper valve **74** and valve **40**. Valve **40** includes a plunger **112** having an alignment portion **106**. Alignment portion **106** is typically a hollow tube. Valve **40** also includes outer tube **108** having a bore which tapers toward an end **110**. Plunger **112** and alignment portion **106** are disposed within outer tube **108**, plunger **112** being disposed toward end **110**. Alignment portion **106** has one or more holes **114** through the side of alignment portion **106**. Alignment portion **106** also tapers toward end **110** to enable liquid to pass through holes **114** when valve **40** is open. It should be noted, that when alignment portion **106** is implemented as a hollow tube, holes **114** are needed. However, if alignment portion **106** is implemented in a different way, such as a X-cross-section tail, holes **114** may not be necessary. An O-ring **116** is disposed between plunger **112** and outer tube **108** to ensure a strong seal of valve **40** when valve **40** is closed. O-ring **116** is disposed, as close to end **110** as possible, to minimize any dead space between valve **40** and upper valve **74**. Valve **40** also includes a spring **118** and a stop ring **120**. Stop ring is mechanically connected to outer tube **108** and spring **118** is disposed between stop ring **120** and the inside of alignment portion **106**, such that spring **118** pushes alignment portion **106** and plunger **112** toward end **110** to seal valve **40**. Valve **40** also has an O-ring **122** disposed on the outer surface of outer tube **108** toward end **110**.

Upper valve **74** is constructed in substantially the same way as valve **40** except that upper valve **74** does not include O-ring **122**. Additionally, upper valve **74** includes a receiving port **124** and an opening pin **126**. Receiving port **124** is configured to receive outer tube **108** of valve **40** such that, valve **40** and upper valve **74** are sealably coupled by O-ring **122** being in close contact with receiving port **124**, prior to either of valve **40** or upper valve **74** opening (Fig. 7). Opening pin **126** is connected to plunger **112** of upper valve **74** such that, when valve **40** and upper valve **74** are pushed together, opening pin **126** causes valves **40, 74** to open (Fig. 8). Once valves **40, 74** are open, liquid can flow through valves **40, 74** via holes **114** in alignment portion **106**.

Reference is now made to Fig. 8. Receiving port **124** includes an absorbent member **128** which is disposed between valve **40** and upper valve **74**. Absorbent member **128** is ~~configured~~ deployed to absorb any remaining liquid which is disposed between valve **40** and upper valve **74** after valves **40, 74** are sealed by being pulled apart. Absorbent member **128** has an absorbency capacity with respect to the liquid flowing through valve arrangement **104**. For the purpose of the description and claims, the "absorbency capacity" is here defined as the ~~measured with respect to a~~ volume of liquid that can be absorbed by member **128** without dripping. To the extent that the absorbency capacity thus defined varies as a function of the liquid composition, water may arbitrarily be chosen as a reference fluid for the purpose of defining this property. Clearly, however, it is the absorbency with respect to the actual liquid fuel which defines the desired characteristics of the system, as described below.

Preferred types of material for absorbent member **128** are chosen to have properties such that they expands beyond their ~~its~~ initial volume as they ~~it~~ absorbs liquid, thereby absorbing a volume of liquid greater than the initial external volume of the member. By way of a non-limiting example, absorbent member **128** can be a SIF felt grade hydrophobic foam, which is commercially available from Foamex International (Eddystone, PA). When valves **40, 74** are sealed by being pulled apart, they define a dead space **130** therebetween. [redacted] In particularly preferred implementations of the present invention, the absorbent capacity of absorbent member **128** is greater than or equal to the total dead space volume between the valves at the moment of sealing. This arrangement has been found highly effective in ~~Therefore, to~~ preventing spilling ~~any~~ of any ~~the~~ liquid residue trapped between valve **40** and ~~upper~~ valve **74** after valves **40**, **74** are sealed~~, dead space **130** has a volume which is less than or equal to the absorbency capacity of absorbent member **128**~~. It will be apparent to those skilled in the art that valve arrangement **104** can be used with many applications, especially those applications requiring non-drip valve arrangements with similar design requirements.

Reference is now made to Fig. 9, which is an isometric view of refillable fuel cell system **10** of Fig. 1 which is interlocked. Reference is also now again made to Fig. 1. Refillable fuel cell system **10** has an interlocking

mechanism **132**. Interlocking mechanism **132** has a component **134** which is mechanically attached to fuel cell assembly **16** of refillable fuel cell **12** and a component **136** which is mechanically attached to fluid replacement assembly **70** of refilling device **14**. To begin removing the spent liquids of refillable fuel cell **12** and to refill refillable fuel cell **12** with replacement liquids, valves **38**, **40**, **46** and **48** of refillable fuel cell **12** are lined up with corresponding valves **74**, **76**, **82**, **84** of refilling device **14**. Refillable fuel cell **12** and refilling device **14** are then pushed together and interlocking mechanism **132** is engaged to maintain the pushing together of valves **38**, **40**, **46**, **48**, **74**, **76**, **82**, **84**. Valves **38**, **40**, **46**, **48**, **74**, **76**, **82**, **84** are now open.

Reference is now made to Figs. 10, which is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber **30** and chamber **72** of refillable fuel cell system **10** of Fig. 9 prior to refilling refillable fuel cell **12**. Once, valves **38**, **40**, **74**, **76**, are open, fuel chamber **30** and chamber **72** define a closed fluid system containing the spent liquid fuel and the replacement liquid fuel, respectively. At this point, piston **88** is at the top of chamber **72**. Piston **88** substantially prevents the liquids flowing through valves **38**, **40**, **74**, **76**.

Reference is now made to Fig. 11, which is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber **30** and chamber **72** of refillable fuel cell system **10** of Fig. 9 during refilling refillable fuel cell **12**. Safety lock **90** (Figs. 5a, 5b) is removed from release bar **92** (Figs. 5a, 5b) and then release bar **92** is displaced laterally to release retaining rod **89**

thereby releasing spring loaded piston **88**. Piston **88** is pushed down through chamber **72** by the spring of piston **88**. In this way, piston **88** pushes the replacement liquid fuel out of chamber **72** via lower valve **76** and into fuel chamber **30** via valve **38**. The replacement liquid fuel enters fuel chamber **30** via turbulence reducing arrangement **50** which substantially prevents mixing of the spent and the replacement liquid fuels in fuel chamber **30**. Substantially simultaneously, piston **88** draws in the spent liquid fuel from fuel chamber **30** via valve **40** of fuel chamber **30** and upper valve **74** of chamber **72**. Additionally, the replacement liquid fuel entering fuel chamber **30** pushes the spent liquid fuel upward towards valve **40**. Mixing of the spent and replacement liquids is substantially prevented in chamber **72** by piston **88**, as described above with reference to Figs. 5a, 5b. It should also be noted that the spent liquid fuel generally has a lower density than the replacement liquid fuel and therefore it may be advantageous for the replacement liquid fuel to enter fuel chamber **30** from the bottom thereof. However, it will be clear to one ordinarily skilled in the art that the invention can be modified such that, the replacement liquid fuel enters fuel chamber **30** from the top thereof and the spent liquid fuel exits chamber **30** from the bottom thereof.

Fig. 12 is a cross sectional view, through a plane which is parallel to lines A-A, of fuel chamber **30** and chamber **72** of refillable fuel cell system **10** of Fig. 9 after refilling refillable fuel cell **12**. Refillable fuel cell **12** now contains the replacement liquid fuel and refilling device **14** now contains the spent liquid fuel. Similarly, the spent electrolyte has been removed from

refillable fuel cell **12** to refilling device **14** and substantially simultaneously, the replacement electrolyte has been inserted into refillable fuel cell **12** from refilling device **14**. The replacement of the spent liquid fuel and the spent electrolyte is performed substantially simultaneously.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and sub-combinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art which would occur to persons skilled in the art upon reading the foregoing description.